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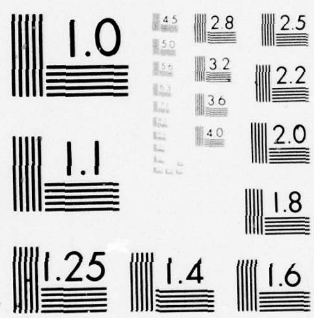

MICROCOPY RESOLUTION TEST CHART
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MANUFACTURING METHODS AND TECHNOLOGY ENGINEERING PROGRAM QUARTERLY TECHNICAL REPORT

Contract Number DAAB07-76-C-8135

LIGHT EMITTING DIODES FOR FIBER OPTIC COMMUNICATIONS

Prepared By:

LASER DIODE LABORATORIES, INC.
205 Forrest Street
Metuchen, New Jersey 08840

Second Quarterly Report
For the Period 1 January 1977 to 31 March 1977

Approved for public release; distribution unlimited.

Placed by:

U. S. Army Electronics Command, Production Division
Fort Monmouth, N. J. 07703

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PROGRAM QUARTERLY TECHNICAL REPORT

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Prepared by:

Albert Gennaro
Product Development Manager

LASER DIODE LABORATORIES, INC.
205 Forrest Street
Metuchen, New Jersey 08840

Second Quarterly Report
for the Period 1 January 1977 to 31 March 1977

This project has been accomplished as part of the Army Manufacturing and Technology Program, which has as its objective the timely establishment of manufacturing processes techniques or equipment to insure the efficient production of current or future programs.

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The design and fabrication of high speed etched-well light emitting diodes for fiber optic communications is discussed with regard to materials synthesis via LPE, wafer fabrication, and device assembly in a manufacturing environment.

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SECTION I

INTRODUCTION

The primary objective of this Manufacturing Methods and Technology Engineering Program is twofold. First, the manufacturing methods and techniques necessary for the volume production of the light emitting diode for use in fiber optic communications as outlined in Specification SCS-511 must be developed and implemented to insure the highest degree of device quality and reliability at a reasonable cost. Secondly, verification of device performance and quality for LED's produced in a volume manufacturing environment must be carried out by means of rigorous testing and evaluation in accordance with SCS-511 in order to demonstrate the technical adequacy of the manufacturing methods developed under this contract.

The major program objectives for the second quarter of the program include the optimization of the epitaxial process to yield material to meet the performance characteristics of SCS-511, construction of device assembly and test fixtures, fabrication of initial engineering samples and the determination of test equipment required for the characterization of the LED.

SECTION II

MANUFACTURING METHODS AND TECHNOLOGY ENGINEERING

2.1 Materials Technology.

2.1.1 Liquid Phase Epitaxial Synthesis of Device Structure.

Sample wafers were grown to determine the melt compositions and growth times that would yield structures compatible with the performance characteristics required by Specification SCS-511. Of the wafers grown during this period, units from BUR-B-19 exhibited the most satisfactory performance with regard to output power and peak wavelength. The performance characteristics of these units are discussed in detail under paragraph 3. Table 1 shows the melt compositions for wafer BUR-B-19. In addition to the melt compositions, growth conditions are listed as well as the individual layer thicknesses obtained from the photomicrograph of a cleaved and stained cross section of the wafer (Figure 1). GaAs ingot and slice numbers are recorded to maintain traceability. Vacuum readings less than 200 μm indicate system integrity and absence of leaks. A hydrogen flow rate of 150 cc/min was maintained for an overnight period in order to reduce the background 0_2 level below 1.0 ppm, prior to the growth run. It has been determined that a minimum of 2 hour flushing is required to produce defect free crystal growth. Although in general the growth process has been optimized, a slight adjustment in the aluminum content of the active layer must be made to bring the peak wavelength into the range as specified by SCS-511.

2.1.2 Wafer Processing for Etched Well Light Emitting Diode Chip Fabrication.

TABLE 1.

DOUBLE HET RUN SHEET

Run # BUR-B-19 Crystal # 8756 Job # 2051

Date March 7, 1977 Slice # 26 Type

Bin #	GaAs Gm	Ga Gm	Dopants		Growth Time Min.	Temp. °C	Layer Thickness µm
1	1	5	2 Te		10	804	1.1
2	2	10	4 Te	10 Al	90	801	10.8
3	1	5	10 Ge	1.5 Al	1.5	784.5	0.5
4	1	5	200 Ge	6.5 Al	15	784	1.3
5	1	5	500 Ge		10	781	1.1
6	1	5	No Dopant		5	779	0.7
7	1	5		50 Al	Wipe	778	-
8	-	-	-		-	-	-
9	-	-	-		-	-	-
10	-	-	-		-	-	-

Vacuum: 150 µ Flow Rate: 150 cc/min. Flush Time: Overnight

O_2 at Ram: 0.75 ppm O_2 at Run : 0.7 ppm Surface Condition: Good

Comments:

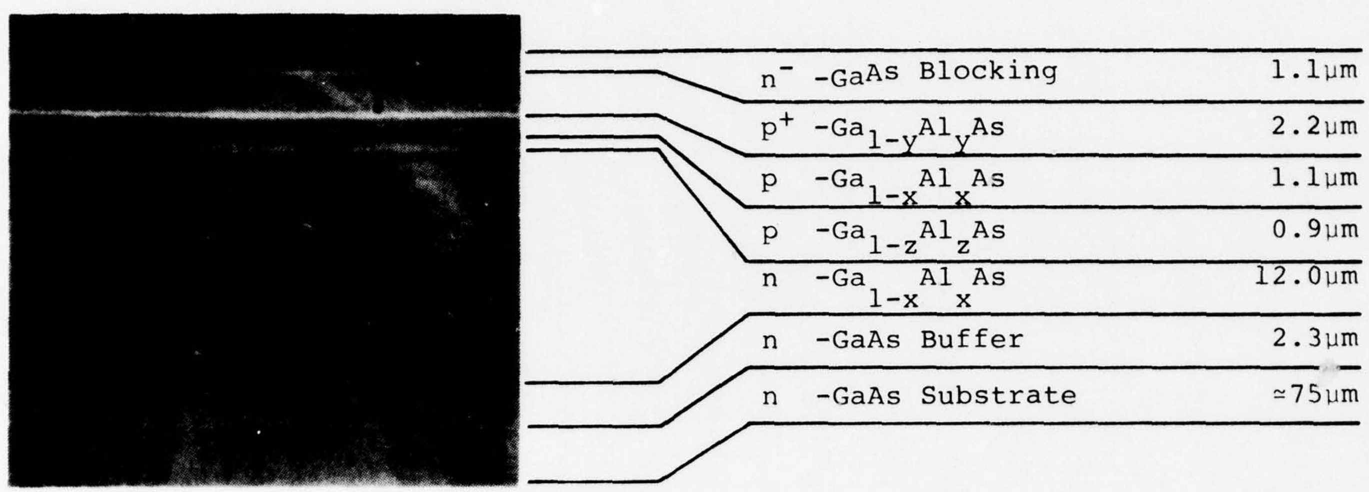


Figure 1. Photograph of Typical Double Heterojunction Structure Required for the Manufacture of Etched-Well Light Emitting Diodes for Fiber Optic Communications.

Figure 2 is a photograph of the hinged mask used to maintain registration of the 'n'-side etch-well and the 'p'-side contact dot. The "hinge" is in reality a continuous strip of metal, which, because of its temper, allows the two masks to be separated slightly but provides sufficient pressure to maintain good mask contact with the epi wafer. A spacer is positioned in the hinge area which allows a separation of the two masks on the order of .005". The wafers to be used with the mask are polished to .0045" $\pm$ .0001" on the 'n'-side of the wafer. A thick (5 μm) layer of Au-Ge is then deposited on the 'n'-side of the wafer. This layer is used as an ohmic contact to the 'n'-side and as an etch mask during the "well" etch step. This eliminates the need for alignment of a contact mask after "well" etching. Photo-resist is applied to both sides of the wafer by spinning it on a teflon vacuum chuck, one side at a time. After a 30 min. cure, the wafer is placed between the plates of the hinged mask. The best cleaved edge of the wafer is positioned against an alignment strip. This strip has been placed parallel to the mask pattern and is used to position the crystal planes parallel to the mask pattern. Exposure of the resist is made by subjecting the mask and wafer sandwich to UV radiation, one side at a time. The exposed photoresist is then developed and the resulting patterns are a 40 μm diameter area of exposed GaAs on the 'p' side, concentric with a 225 μm diameter area of exposed Au-Ge over GaAs on

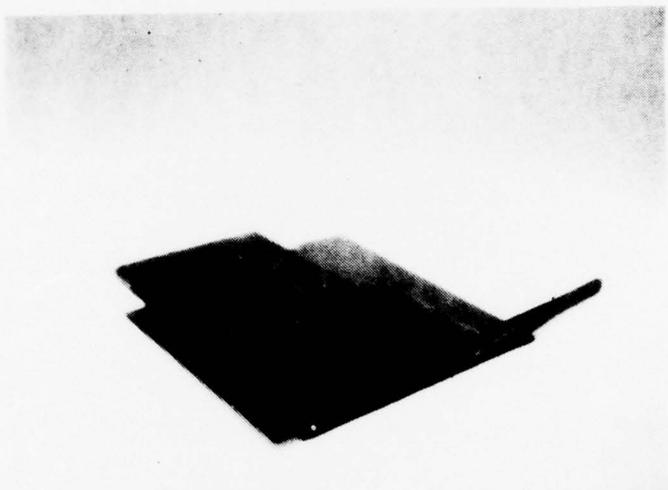


Figure 2. Hinged Photomask.

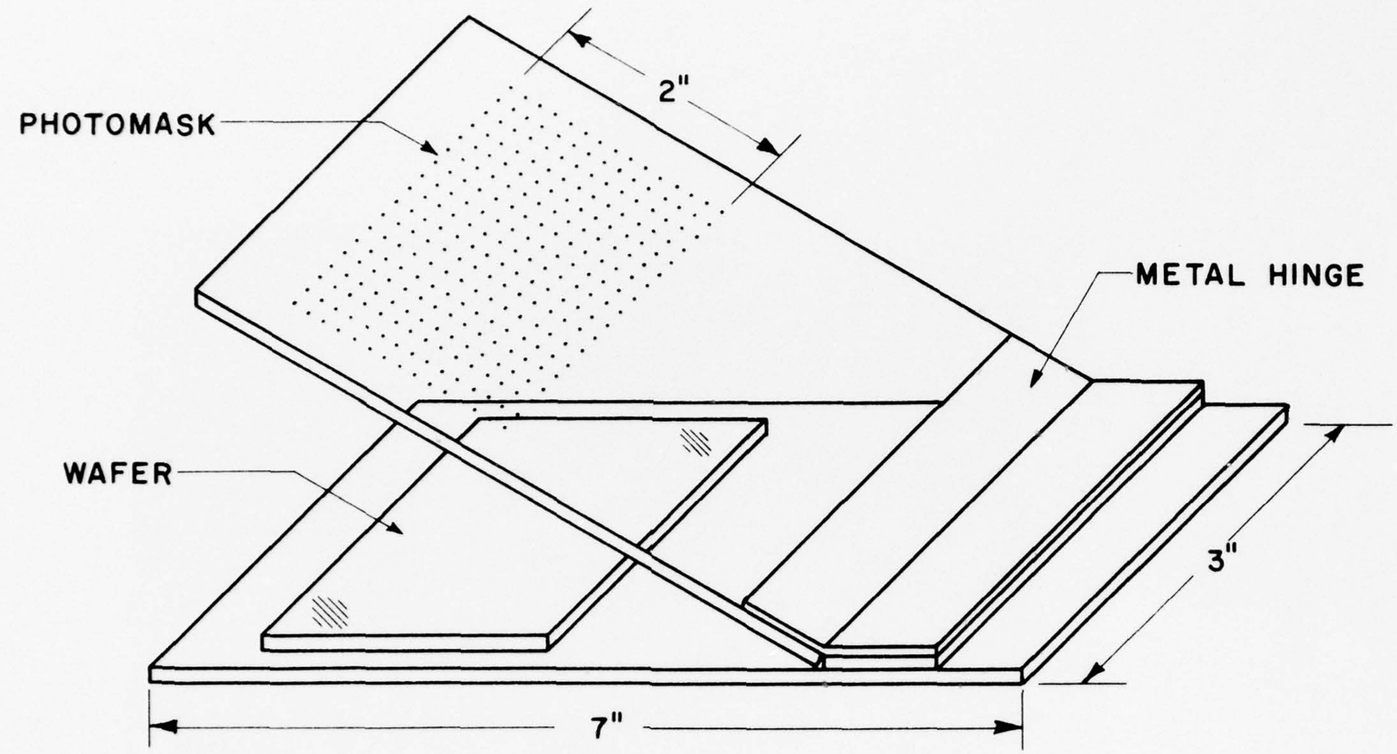


Figure 3. Sketch of Hinged Photomask.

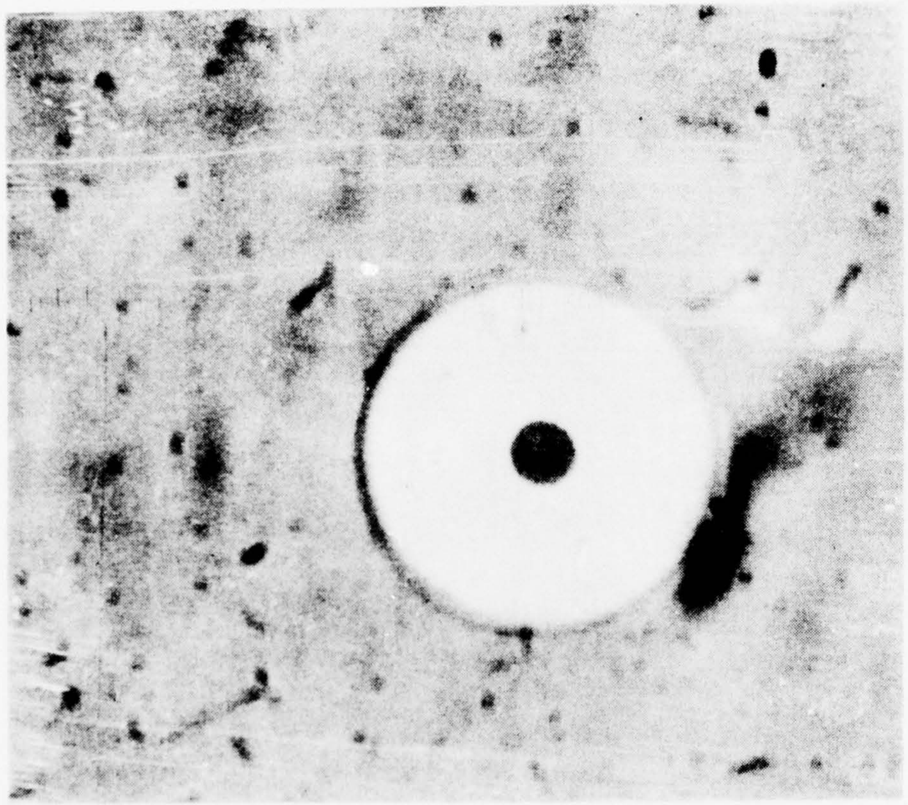


Figure 4. Photomicrograph of Prealigned Photomask Showing Contact Aperture Centered in the Fiber Well.

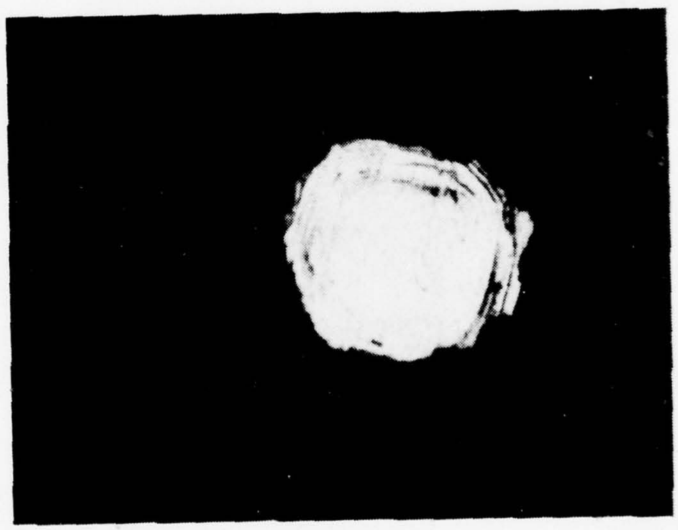


Figure 5. Etched Well.

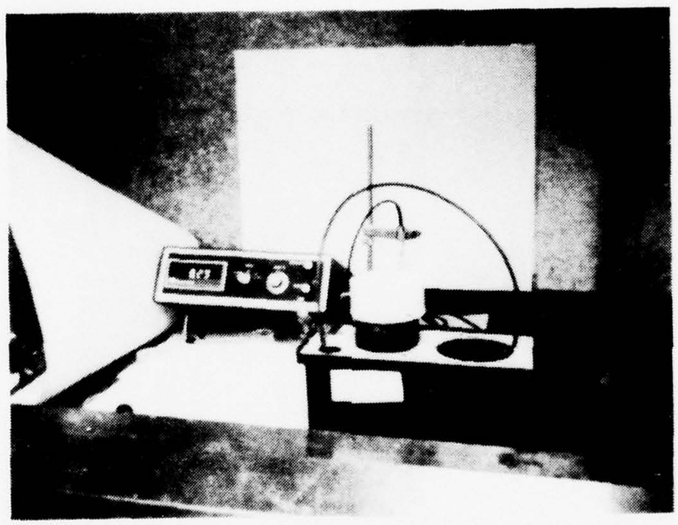
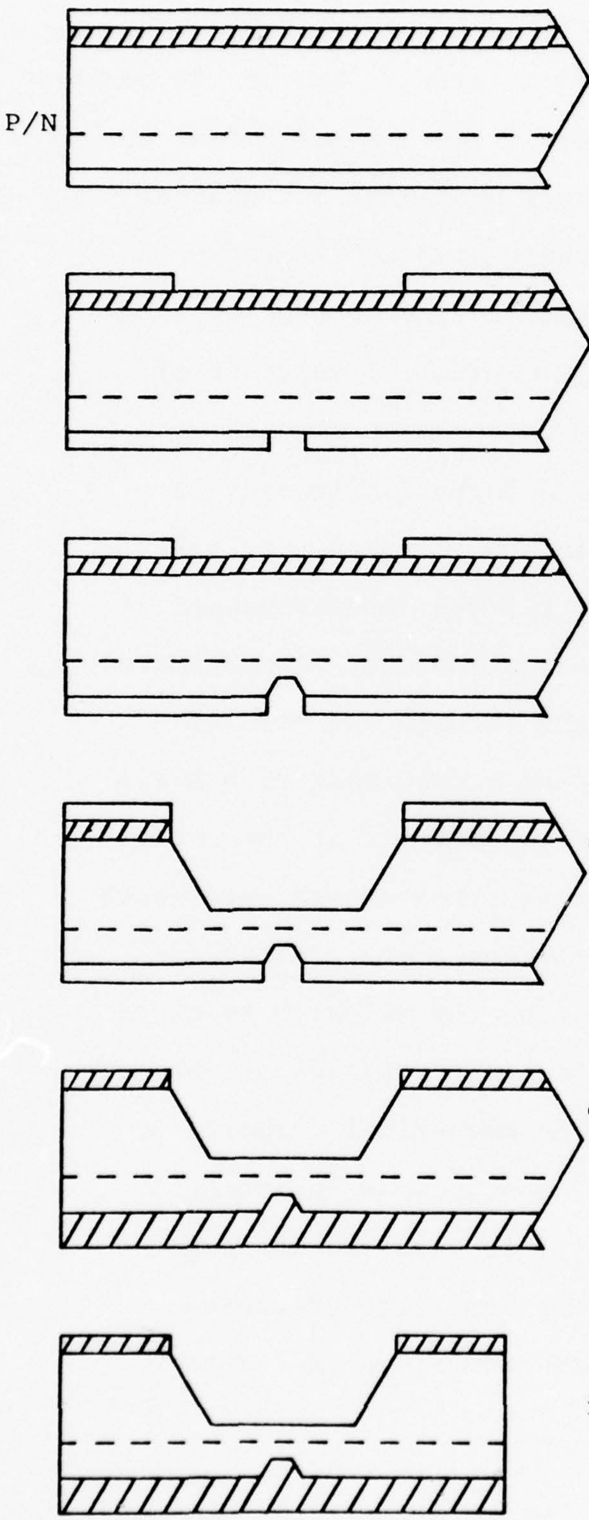


Figure 6. Spray Etch Equipment.

Figure 7. Wafer Processing Flow Chart for the Manufacture of Etched-Well Light Emitting Diodes.



a) Evaporate Au-Ge onto n-side of wafer. Coat both sides with photoresist.

b) Expose and develop resist using prealigned photomask to expose both sides simultaneously.

c) Etch p-side aperture with 3:1:1 H_2PO_3: H_2O_2:H_2O through blocking layer.

d) Spray etch well with pH adjusted NH_3OH:H_2O_2.

e) Strip resist and electroplate p-side of wafer to form integral heat sink.

f) Wire saw wafer into discrete diodes.

the 'n' side. Figure 3 depicts the alignment of the contact and the well. The 'p' side contact is etched by immersing the wafer in 3:1:1 ($H_2PO_3:H_2O_2:H_2O$). This etch removes only the exposed GaAs at a rate of .09 μm/sec. An etch time of approximately 15 sec. is sufficient to etch through the blocking layer and about one-quarter of the 'p' contact layer. The 'p' side of the wafer is next waxed to a glass slide to provide protection from the well-etch solution. A pH controlled solution of $NH_3OH:H_2O_2$ is sprayed on the wafer in 5 minute intervals, after which time, a depth measurement is taken, and the pH of the solution adjusted. It has been determined that a pH of 8.3 must be maintained in order to obtain a controllable etch rate. Approximately 20 minutes is required to etch through 3.5 mils of GaAs. Figure 4 shows a typical etched well with a 9.5 mil diameter at the 'n'-surface, and 6 mil at the bottom of the well. Figure 5 shows the pressurized spray-etch apparatus and the pH measuring equipment. After demounting, stripping and cleaning the wafer, a thick Au film (~10 μm) is electroplated on the 'p' side of the wafer. This plating serves to provide mechanical support for the thin active region, and functions as an integral heat sink. Finally, the wafer is wire-saw cut into diodes of .020" x .020" dimensions. The processes described in this section are summerized in Figure 6.

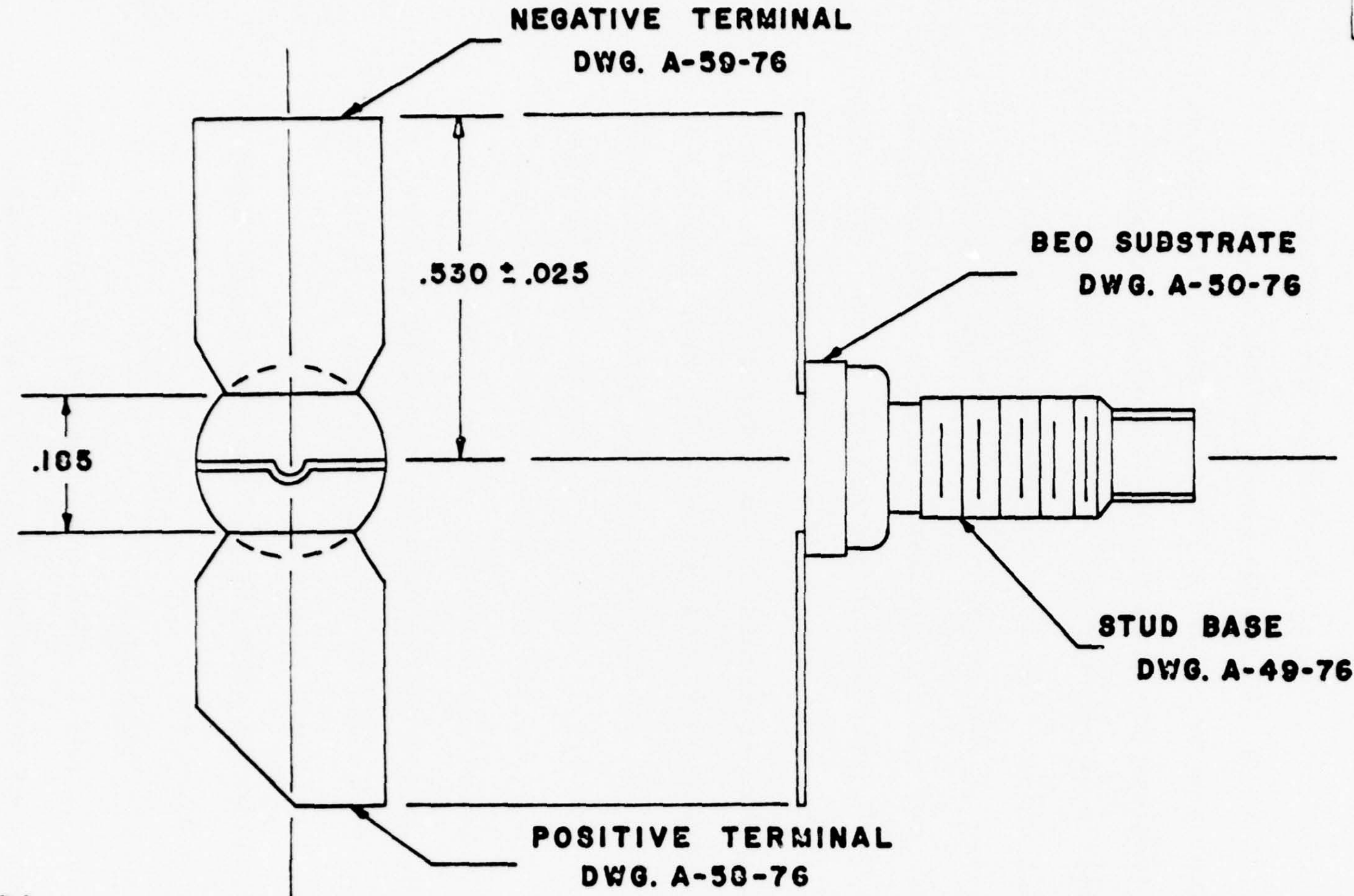
2.2 Packaging Technology.

2.2.1 Package Design.

The stud assembly shown in Figure 7 is a modified RF transistor package (JEDC MT-90). The processed .020" x .020" LED chip is mounted on the semicircular area, which is on the center lines of the assembly. Early samples were indium soldered to the BEO. Because the P-N junction is close to the bottom of the pellet, many diodes were shorted due to indium "wick up" the pellet sides. The current process uses silver filled epoxy as the mounting medium. This is a two part epoxy and can be formulated to reduce the capillary action. The 'n'-side pellet connection to the corresponding area on the BEO is made with a 1 mil gold wire, indium soldered at each end. An ultrasonic wire bonding fixture for this stud assembly has been fabricated and will be used on all subsequently manufactured units. The fiber assembly is shown in Figure 8. The ferrule is free to move within the sleeve, providing an axial degree of motion necessary for fiber to diode alignment. Due to the unique characteristics required by SCS-511 manufacturing of the ferrule assembly has been further delayed. Substitute fibers are being investigated. Figure 9 shows the separate package components along with a completed unit.

2.3 Diode Assembly Technique.

Figures 10, 11 and 12 show the alignment fixture along with associated equipment. The measuring equipment

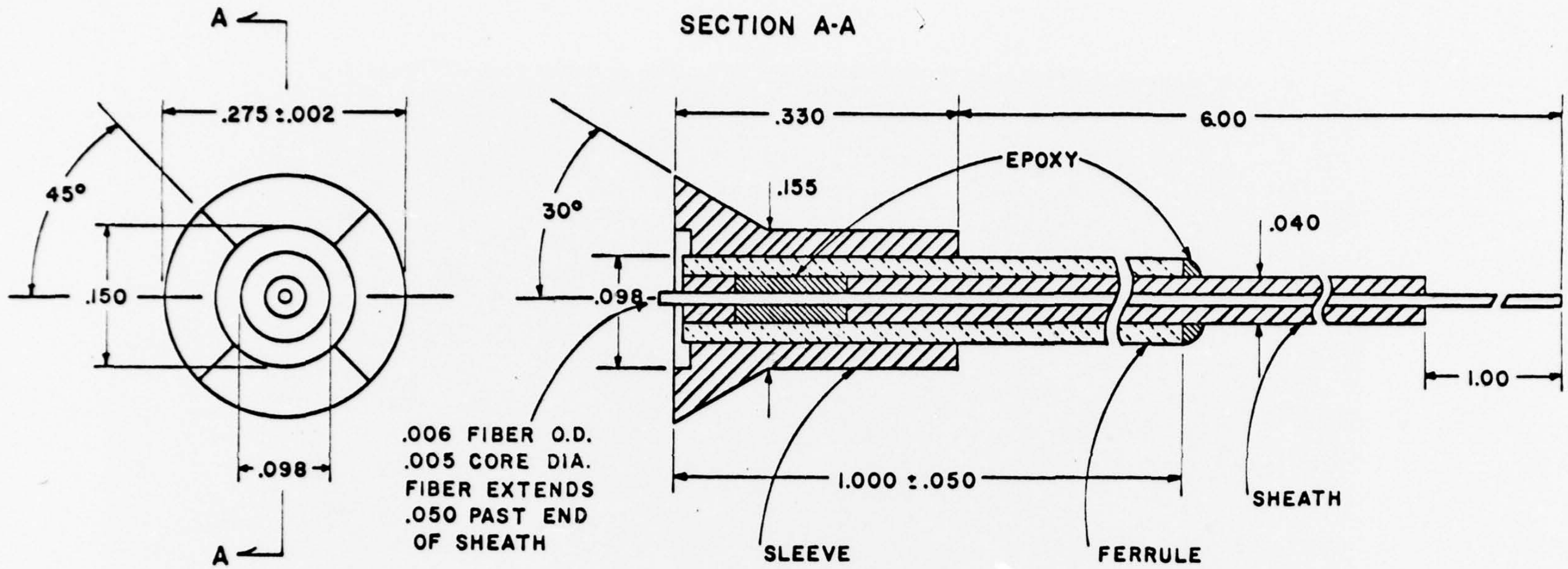


NOTES:

1) ASSEMBLE PARTS WITH BRAZE AT 600° C MIN.

2) FINISH –
DIE BOND AREA, 150 μin. AU ONLY
STUD, 150 μin. NI, IMMERSION AU
LEADS, 80 μin. AU

LDT 177 STUD ASSEMBLY		
SCALE: 4X	APPROVED BY	DRAWN BY M.R.
DATE: 12-10-76		
Figure 8. LED Stud Assembly.		
LASER DIODE LABS. INC.		DRAWING NUMBER A-40-76



FIBER CHARACTERISTICS

CHARACTERISTICS	MIN.	MAX.	UNIT
ATTENUATION (AT λP) (8200Å)	–	50	db/km
CORE DIAMETER	–	125	um
CLADDING DIAMETER	150	–	um
PROTECTIVE JACKET DIAMETER	1	–	mm
NUMERICAL APERTURE (N.A.)	–	0.3	–
TENSILE STRENGTH	50	–	NEWTONS
BENDING RADIUS	1.5	–	mm

LDT 177 FIBER ASSEMBLY

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Figure 9. LED Fiber-Ferrule Assembly with Support Sleeve.

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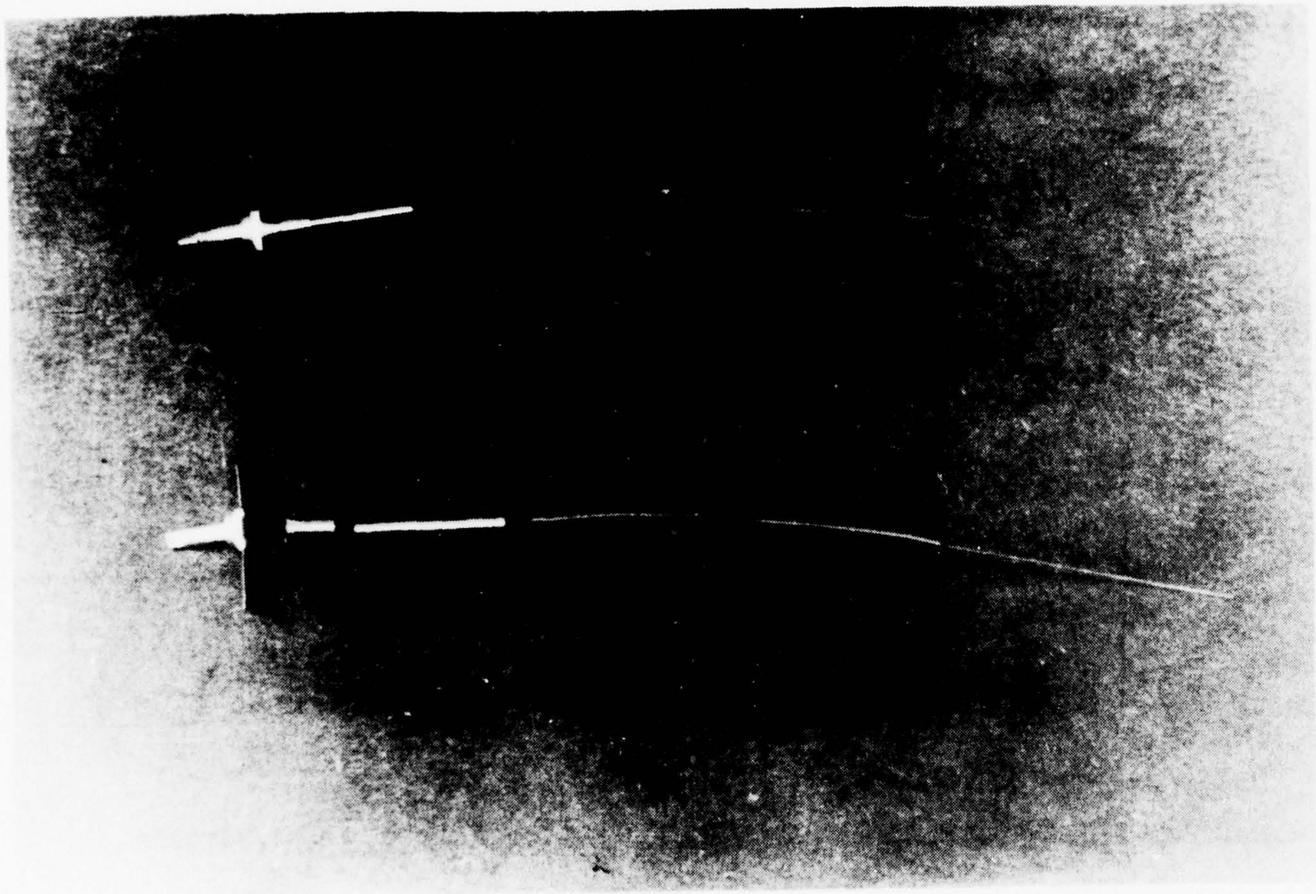

Figure 10. Package Components and Completed Assembly.

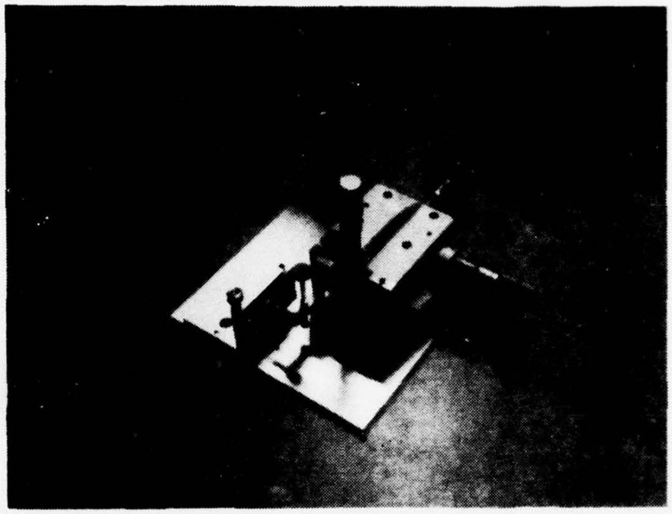

Figure 11. Alignment Fixture.

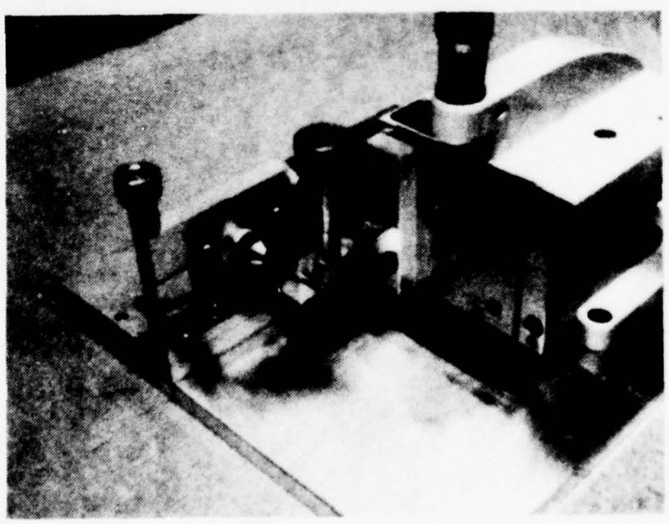

Figure 12. Alignment Fixture (Close-Up).

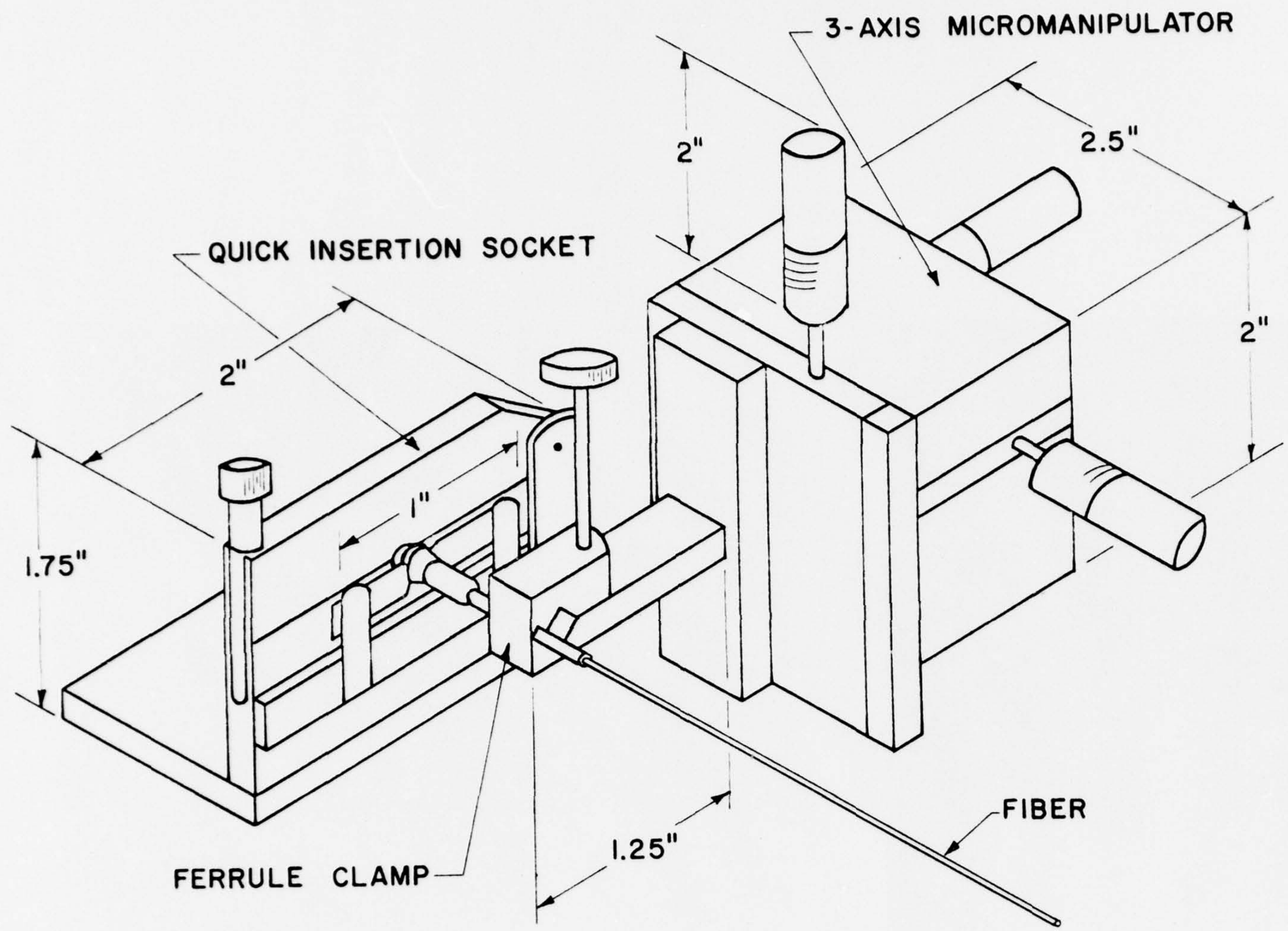

Figure 13. Sketch of Alignment Fixture.

Figure 14. Alignment Fixture and Power Measuring Instrument.

consists of an EG & G 460-1 laser power meter and the 460-2 silicon detector. The detector features high sensitivity, long term stability, excellent linearity of response over a wide dynamic range, and ultra-low noise levels. The alignment fixture incorporates a quick insertion diode socket which minimizes damage to the stud and leads. At the same time the socket clamp applies sufficient pressure to keep the diode in position during fiber alignment. The 3-axis micromanipulator has attached to its platform the ferrule-sleeve quick release clamp. In practice, the ferrule is placed in the micromanipulator clamp in such a manner that the sleeve may be slid back to expose the fiber protruding from the front of the ferrule. The fiber pigtail is positioned in front of the detector. Under microscopic examination, the fiber is maneuvered in the diode well, while oberving the laser power meter for a maximum reading with the diode forward biased. By rotating the sleeve on the ferrule, epoxy can be applied to the supporting faces of the sleeve. The sleeve can now be slid forward and placed in contact with the BEO mounting surface. The joint between the sleeve and the ferrule is epoxied. After curing the assembly becomes a rigid structure and can be removed from the fixture.

2.4 Device Evaluation and Testing.

2.4.1 Device Evaluation.

Table 2 is data recorded on samples from lots 16 and 19.

TABLE 2.

Etched-Well LED Data.

Sample	Drive Current 100 mA P_O (mW)	λ peak	V_F (20 mA)	V_R (10 μA)
16-1	.377	839	2.6	1.7
16-2	.490	839	1.6	1.1
19-1	.320	792	1.8	1.8
19-2	.352	782	1.9	2.8
19-3	.345	783	1.8	4.5
19-4	.335	784	1.9	6.4

I_F = 100 mA.

P_O measured into 0.3 N.A.

The spread in peak wavelength between the lots is indicitive of the adjustment of the aluminum content of the active layer needed to bring the λ peak within the 800 to 830 nm specification. The P_O radiant intensity is a bare diode measurement where the detector is placed 1.58 cm from the diode, with an exposed detection area of 1 cm. diameter and $\theta \cong 34°$ cone. The low reverse voltages indicate excessive leakage due to the epoxy wetting the sides of the pellet and degrading the junction.

2.5 Test Equipment.

Figure 13 is the circuit for a fast pulse driver. This circuit has been designed to be used with an HP 8082A pulse generator to measure pulse time and thermal impedances.

Selection of specific commercial equipment to implement specification testing is being narrowed. The signal source for bandwidth testing which will feed the wide band driver may be a Boonton Radio Model 103, a Genrad Model 1211, or an HP Model 606B. The spectrum analyzer may be a Tektronix 7612/7603, or HP 8553B/8552B/140T or a Polrad 632. The wideband detector may be a B & H OC3002, or some equivalent unit. Figure 14 is the circuit for a wide band sine wave driver for use with the signal sources mentioned previously. A transient suppressor for use with any constant voltage-constant current supply is shown in Figure 15. This circuit is currently in use for all D.C. testing.

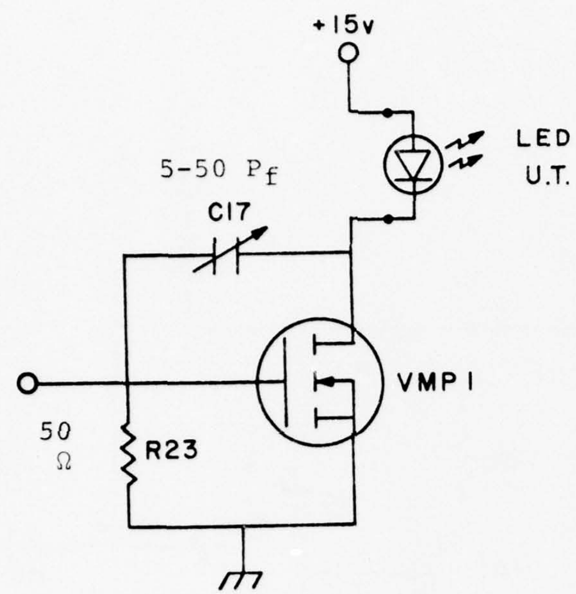

Figure 15. Pulse Driver

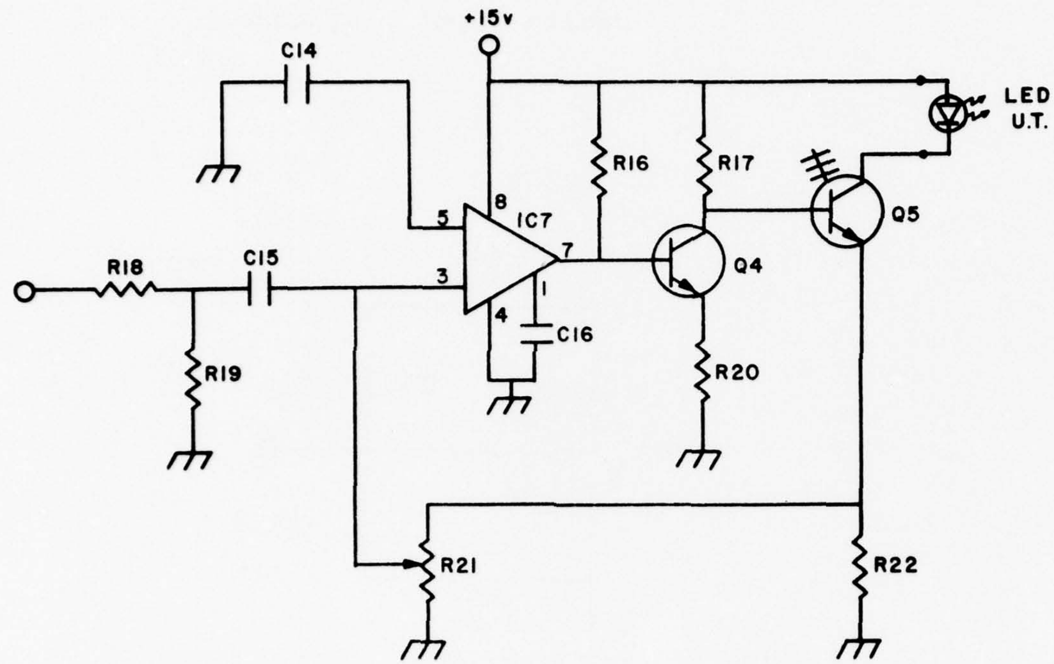

Figure 16. Sine Wave Driver.

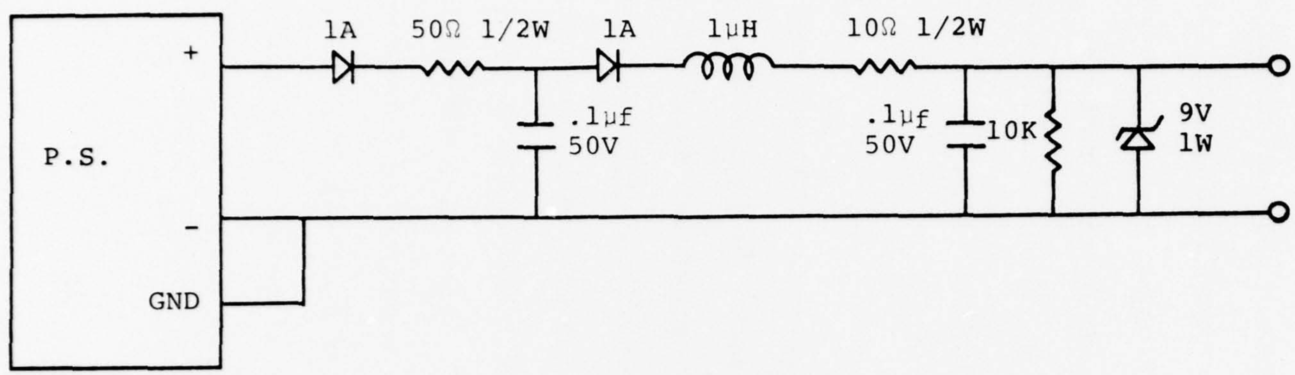

Figure 17. Transient Suppressor.

A new goniometer has been designed, built and tested. Figures 16 and 17 show two views of the apparatus. The head is turned manually and the self contained circuitry allows scale adjustment and control of a chart recorder. The head section is interchangeable for various device considerations. A block diagram of the internal circuitry is shown in Figure 18. Figures 19 and 20 illustrate a quick insertion and removal socket which, in various forms, is being used for all testing.

2.5.1 Life Testing and Burn-In.

A combination life rack and burn-in rack has been designed. The circuitry is shown in Figure 21. Components have been selected to operate the diode at 100 mA forward current. An individual 6 position section can be inserted into or removed from the main rack without shutting down the entire rack. Each section is configured to fit within the main rack with diodes in a vertical position and pigtails protected from accidental damage. The total capacity of the rack will be 150 units. Provisions have been made to allow adequate air flow by utilizing several high capacity fans.

SECTION III

SUMMARY AND CONCLUSION

During the second quarter of the program, bare diodes were made which exhibited the essential characteristics required by SCS-511. Epitaxial and well etching processes

have produced material and devices of the proper conformation. The lack of a suitable fiber or fiber assembly has delayed the testing of finished engineering samples.

Plans for the next quarter include fabrication, testing, and delivery of the second engineering samples. In addition, it is expected that test and evaluation facilities will be available to fully characterize the devices. Life test and burn-in racks should be completed and available for use during this period.

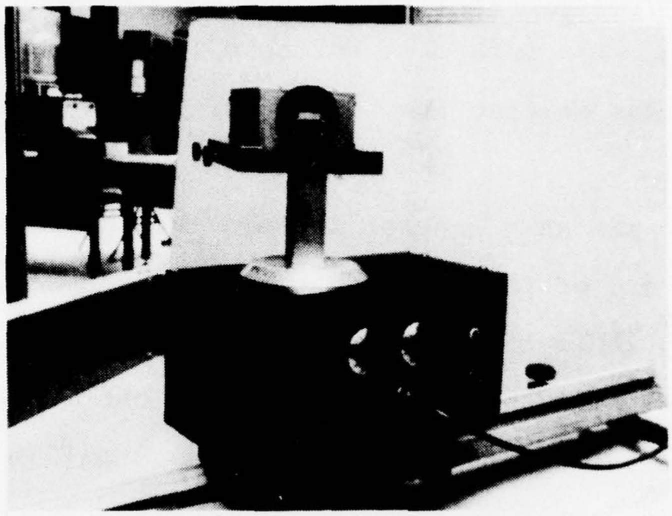

Figure 18. Photograph of Goniometer Showing Rotatable Head.

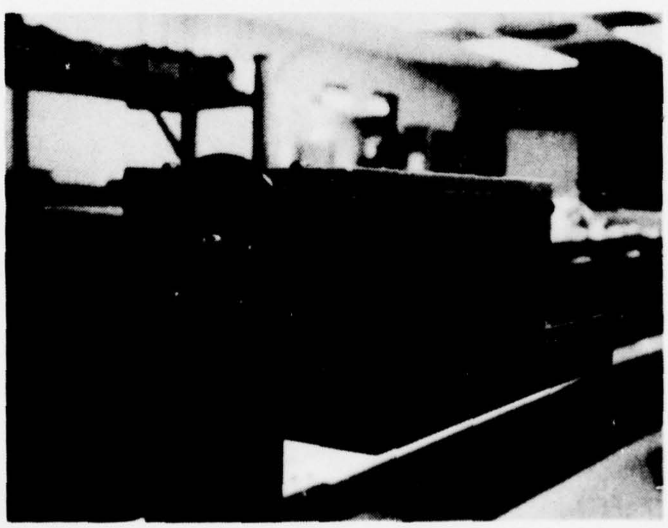

Figure 19. Photograph of Goniometer Showing Close-Up of Mounting Fixture.

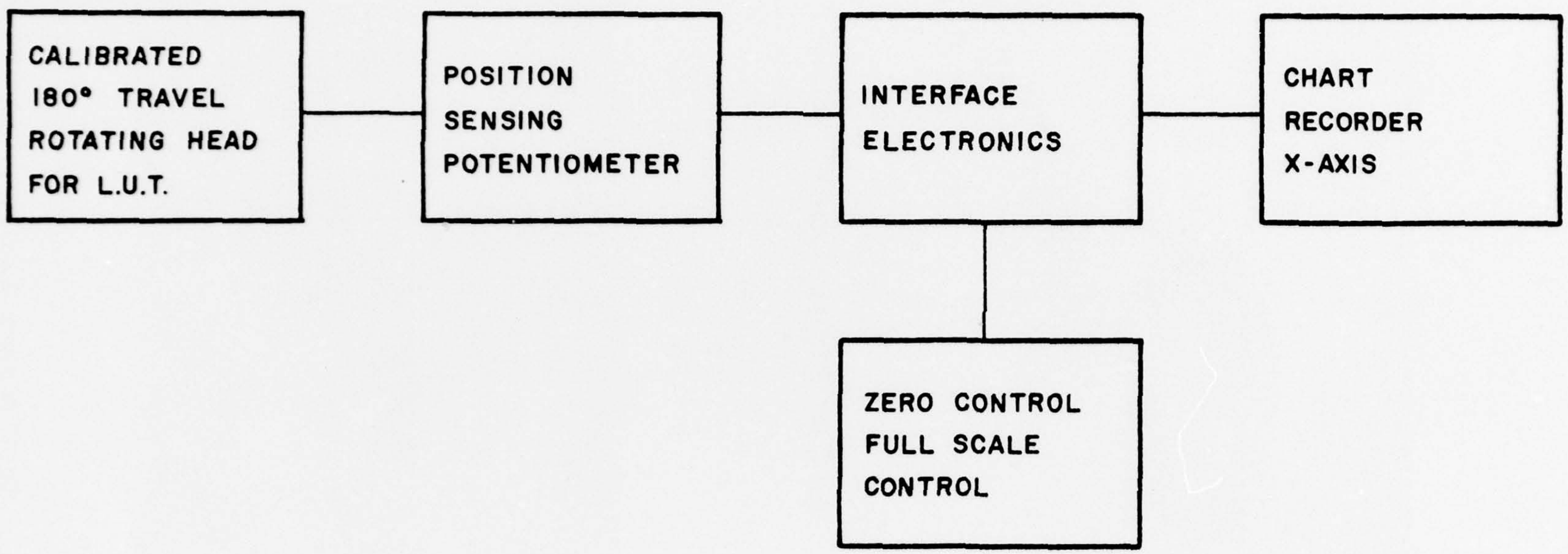

Figure 20. Goniometer Block Diagram.

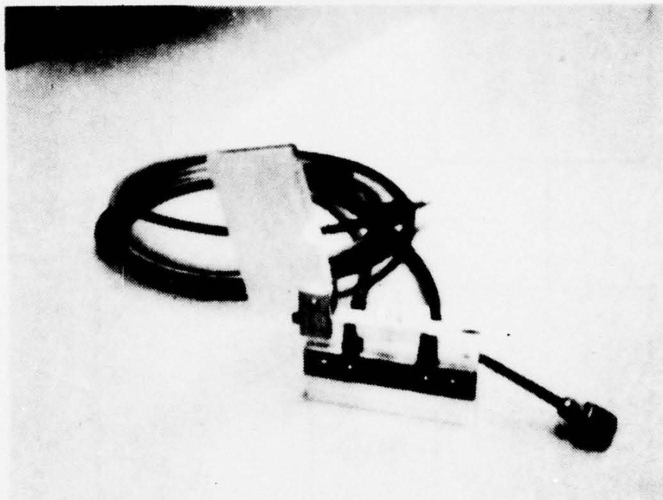

Figure 21. Test Socket in Open Position.

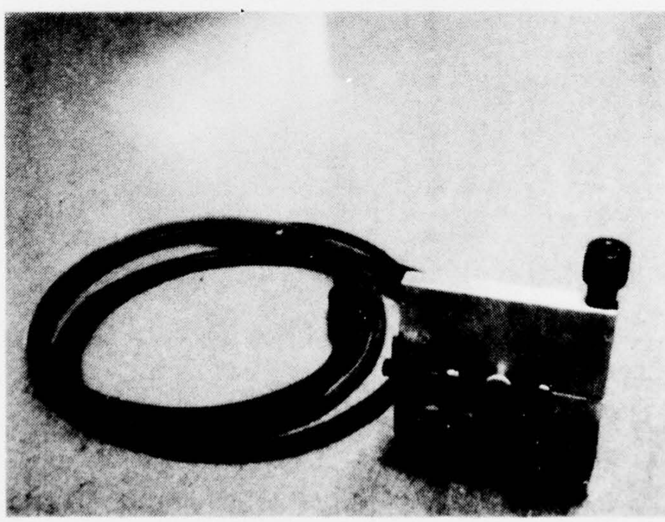

Figure 22. Test Socket in Closed and Clamped Position.

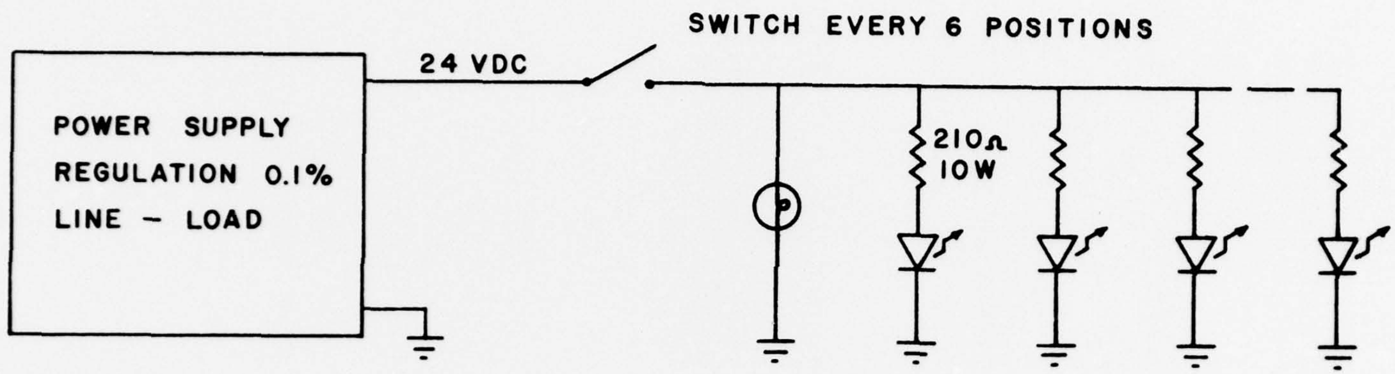

Figure 23. Burn-In and Life Rack Circuitry.

APPENDIX A

Engineering Man-Hour Utilization for
the Second Quarter of the Program.

	2nd Qtr.	Cumulative
T. E. Stockton	108 Hrs.	284 Hrs.
R. E. Albano	96 Hrs.	216 Hrs.
A. Gennaro	116 Hrs.	181 Hrs.
R. B. Gill		88 Hrs.
S. Klunk		16 Hrs.
Manufacturing Personnel	636 Hrs	1160 Hrs.

APPENDIX B

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